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WASTE MINIMISATION STRATEGIES AT THE DESIGN PHASE: ARCHITECTS' RESPONSE

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ABSTRACT

Effective minimisation of construction material waste has demonstrated that environmental pollution arising from construction activities can be reduced. Yet, there is insufficient knowledge on the role of architects in minimising waste, especially at the design phase. The purpose of this article is to identify the causes, barriers, approaches, driving factors to waste minimisation and to investigate strategies employed by architects at the design phase. This study adopted a survey questionnaire with both open and close-ended questions to elicit information from architects in Akure, Ondo State, Nigeria. Empirical results indicate that the major cause of waste at the design phase is the client's last minutes changes to design. Design for flexibility and adaptability and lack of training were the top approach and barrier to construction waste minimisation respectively. The driving factors were training, waste *management policy and legislation while the top three strategies employed by the architects are modular coordination, proper detailing and market survey. Findings recommend that the design checklist be created and implemented, that waste minimisation options be considered and that architects take more responsibility for their actions during the design phase.*

Keywords: architects; design; design phase; Nigeria; strategies; waste minimisation.

1.0 INTRODUCTION

The construction industry remains a force to be reckoned with in the sense of global development. For instance, the industry accounts for about 13% of the global economy (Global Construction Perspectives, 2013). In addition, its ramification cut across other sectors, such as manufacturing, tourism, healthcare and education, through the provision of infrastructure. While the socio-economic benefits of the industry cannot be overemphasised, there are also some negative aspects. Construction activities consume a great deal of resources and generate a significant amount of waste that contributes to environmental degradation (Solis-Guzmán et al., 2009). For example, the United Kingdom generates 100million tonnes of construction waste (CW) in 2012 (DEFRA, 2015). As of 2015, construction activities contribute about 45million tonnes of waste in Brazil (Brazilian Association of Public Cleaning and Special Waste Companies ABRELPE, 2014) while Malaysia, generates 26,000 tonnes daily due to the accelerated growth of cities (Zulzaha, 2014). In Nigeria, the incidence of CW is high due to growth of the industry and urbanisation (Wahab and Lawal, 2011; Odusami et. al., 2012). Construction activities and material waste pose a significant threat to sustainable development, which has increased the need to tackle its environmental effects in the form of pollution. Waste generated from construction activities and materials contribute to pollution.

Construction material waste (CMW) is an excess resource used in the construction of a project. Approximately 10–15% of the materials estimated for the construction of a project can lead to waste (Wong and Yip, 2004). Previous studies (Ogunmakinde, 2019; Mata et al., 2014; Al-Hajj and Hamani, 2011; Oladiran, 2009) have reported different causes of CMW. Nagapan et al., (2012) classified CW as physical (material waste) and non-physical waste (cost overrun, and time overrun). Design quality, design changes, material handling and storage, poor supervision and transportation influence waste generated during construction activities (Odusami, et al., 2012; Aiyetan and Smallwood, 2013; Eze et al., 2017). In addition, the lack of familiarity with construction methods, the use of non-professional, sub-standard services rendered by professionals and the lack of professional commitment to quality in terms of project delivery also influence the waste volume during construction (Oyewobi and Ogunsemi, 2010; Ganiyu et al., 2016). These waste causes on construction sites however require effective management to reduce the volume generated.

Waste management has become a major topic of discussion in the construction sector in recent times. Wahab and Lawal (2011) argued that the continuous rise in the volume of waste produced is largely related to availability of limited disposal options and lack of awareness. Corroboratively, Kareem et al. (2015) posited that lack of regulatory and organisational policies also impedes the effectiveness of available waste management measures. Researchers have employed various methodological tactics to study waste management approaches during the construction phase of project delivery (Oladiran 2009; Adedeji et. al, 2013; Adewuyi, 2012; Adewuyi and Odesola, 2016). The literature acknowledged some potential waste management methods adopted by Nigerian construction industry such as landfilling, reuse and recycling (Dania et. al, 2007; Odusami et al., 2012; Kofoworola and Gheewala, 2009; Ganiyu et al., 2016; Ogunmakinde, et al., 2019). Despite the various methods adopted by the construction industry, CW continues to be a major problem in Nigeria needing an urgent solution.

Sustainable waste management is designed to reduce, reuse and recycle materials, which is the 3Rs principle (Yuan and Shen, 2011). Waste reduction improves resource management, reduce demand for landfill spaces and saves cost (Tam and Tam, 2006; Yuan, 2013). Waste minimisation can be considered as one of the most effective sustainable strategies for managing CW. This suggests that waste must be reduced before it is produced. While waste can be minimised throughout the construction processes, it is often significant at the planning phase where a lot of decisions are made. The decision-making process for any project at the conceptual planning and design phase enables CW source control (Faniran and Caban, 1998; Ekanayake and Ofori, 2004; Osmani, 2013; Yuan, 2013; Yang et al., 2017). The design stage offers a greater opportunity to minimise waste during the construction process because major decisions on building form, size, complexity and materials influence the amount of waste generated during the subsequent stages of project life cycle (WRAP, 2013).

Research from developed countries has made a major contribution to understanding the causes of waste and effective waste minimisation through design by seeking the opinions of construction stakeholders (Baldwin et al., 2009; Osmani, 2012; Udawatta et al., 2015; Liu et al., 2015; Ajayi, 2017). Some studies from developing economies such as China (Wang and Yuan, 2011; Li et al. 2015; Wang et. al, 2014) and Malaysia (Ramayah et al., 2012; Esa et al., 2017) have also evaluated the CWM through design. However, there is little, or no research work related to waste minimisation by design in this part of the world (Nigeria). Accordingly, this study seeks to fill this void by examining the roles played by Nigerian architects in minimising CW during the design process. The objectives of the study are:

i. to identify the causes of construction waste, design approaches, barriers and driving factors to waste minimisation at the design phase; and
ii. to investigate appropriate waste minimisation techniques or strategies employed at the design phase.

The following section of this paper presents an overview of causes of CW at the design stage, approaches and barriers to the adoption of construction waste minimisation design. The section that followed discussed the methodological approach while the last two sections addressed the findings and the conclusion of the study.

2.0 LITERATURE REVIEW

2.1 Causes of Waste

According to Esa et al. (2017), the process of managing CW is effective at the planning and design stage. Several studies (Gamage et al., 2009; Ekanayake and Ofori, 2004; Polat and Ballard, 2004; Garas et al., 2001) have shown that most of the CW generated is induced by design. During the design phase as described in the literature, the causes of waste include: design changes, design and detailing errors, material specification, design and detailing complexity and ineffective communication and coordination among the design team (Keys et al., 2000; Faniran and Caban, 1998; Al-Hajj and Hamani, 2011; Osmani et al., 2008; Osmani, 2013; Lui et al., 2015). Design changes occurs as a result of last-minute changes in clients' requirement, design errors that requirements amendments to the design and the need to work within an estimated budget (Zhao and Chua, 2003; Ekanayake and Ofori, 2004; Aiyetan and Smallwood, 2013; Osmani et al., 2006). For example, Osmani et al. (2008) examined organisational waste management issues and found that inadequate design brief and lack of standard dimensions were the main causes of waste identified by contractors and that most architects in the United Kingdom did not consider waste minimisation in their design.

Design and detailing errors often lead to inadequate information required for the buildability of a project, which consequently leads to rework (Faniran and Caban, 1998; Oluwaseun and Olumide, 2013; Aiyetan and Smallwood, 2013). Oyewobi and Ogunsemi (2010) revealed that poor design documentation is one of the factors influencing rework occurrences on construction sites. Furthermore, a lack of clarification on the quantity and quality of materials needed for a construction project can lead to waste (Ekanayake and Ofori, 2000; Osmani, 2012). Odusami et al. (2012) examined material wastage and control measures employed in some construction sites and found that over estimation of the quantity of material led to material wastage. As echoed by Nagapan et al. (2013), design and detailing complexity contributes to physical and non-physical waste. Similarly, Osmani (2013) reported that ineffective coordination and communication among the project team contributes to CW. As observed by Oyewobi and Ogunsemi (2010) lack of coherence between the design and construction stage causes reworks. It is clear from the foregoing that waste can be generated during the design process. Nonetheless, it can be minimised, which suggests the need to implement measures during the design process to reduce waste generation.

2.2 Construction Waste Minimisation Strategies

Minimisation of waste through design is a crucial technique for successful waste reduction (Baldwin et al., 2009). Previous studies have identified architectural design strategies and modern construction methods for reducing waste during the design process (Poon and Jaillon, 2002; Shen et al, 2009; Adedeji et al., 2013, Yeheyis et al., 2013; Yuan, 2013; Ajayi et al., 2017). In a study conducted by Wang et al. (2014), factors including the use of prefabricated components, modular design, large panel metal formworks, design modifications, economic incentive and waste reduction investment were considered crucial for minimising waste during the design process. Similarly, Ajayi et al. (2017) indicated that the use of standardisation and dimensional coordination, adoption of modern construction techniques, components and spatial flexibility, preparation of deconstruction plan and use of BIM for building coordination are crucial to a waste efficient design. According to Jaillon et al. (2009), about 84.7% of CW can be reduced if off-site prefabricated and standardised components are used. Shen et al. (2009) also observed that the use of prefabricated materials has cost saving benefits and may improve the environmental performance of materials. Similarly, using prefabrication for timber formwork can reduce about 87% of waste, while approximately 60% of waste can be reduced through prefabrication for concrete works, as argued by Tam et al. (2005). However, the adoption of prefabrication techniques have been limited due to transportation cost of precast elements to construction sites, heavy-duty tower cranes and large storage space required, higher investment cost as well as inflexibility to design changes during construction (Baldwin et al., 2009, Jaillon and Poon, 2009).

Subsequently, some studies have recommended dimensional coordination, standardisation of building elements and design for flexibility and adaptability (McKechnie and Brown, 2009; Yuan, 2013; Alshboul and Ghazaleh, 2014). Flexibility of building spaces allow for easy modification of the spatial configuration resulting in less waste in future changes. Another strategy to minimize CW is to design for deconstruction (Tingley and Davison, 2011; Osmani, 2012; Adams, 2015). This involves designing, organisation and selection of building materials that will allow for careful demolition of the building elements (Saghafi and Teshnizi, 2011; Ajayi et al., 2017). Deconstruction plan should be prepared alongside other design documents. Gangolells et al. (2014) proposed that attention be given of recycled building elements to reduce waste. Technology in the form of Building Information Modelling (BIM) has also been proposed as an effective strategy to minimise waste at the design phase (Liu et al., 2015; Sacks, et al., 2010). According to Liu et al. (2015), the use of BIM for project coordination provides an informed guidance to decision-making process of designing out waste.

It is apparent from the foregoing that architectural design strategies and modern construction methods, including technology, can be effective in minimising construction waste. More so, the uniqueness of the construction industry needs to be considered in order to determine appropriate approaches. The need to identify design strategies currently used by Nigerian architects to reduce waste generation during the design phase is therefore required. In addition, it is important to understand barriers and factors affecting the implementation of design strategies.

3.0 METHODOLOGY

The purpose of this study is to identify the causes, approaches, barriers, incentives and appropriate strategies to waste minimisation at the design phase. The study was conducted in Akure, Ondo State, Nigeria. To achieve the aim of this study, a quantitative research was adopted. Quantitative research methods are appropriate for quantifying opinions, perceptions, attitudes, and are more reliable, objective and findings can be generalised (Saunders et al., 2007). The study design adopted the survey process, which used questionnaires to collect numerical data. This allows for a vast number of people to be reached conveniently in a cost-effective manner. Participants were recruited through a simple random sampling from the Nigerian Institute of Architects, Ondo State chapter. According to the Architects Registration Council of Nigeria (2004), the first two years after graduation are periods of tutelage or internship with a registered architect. Therefore, architects with less than three years of experience have not been included in the study because they are unlikely to make informed decisions about the design. Only architects with minimum of three years of experience in design and construction were included in the study. They were invited to respond to an online questionnaire hosted on www.surveymonkey.com. A pilot test of the questionnaire was performed with five architects in the

Department of Architecture, Federal University of Technology Akure, Ondo State, Nigeria, to achieve content validity based on their knowledge of design processes. The questionnaire was refined based on comments and suggestions made in the pilot test. For instance, the choice of words, the presentation, the sections and the completion time were revised. The questionnaire was emailed to all potential participants with a link to the online survey, while the objectives of the study were included to enhance participants understanding of the phenomenon. Consent was implied by the return of the completed survey. The questionnaire was structured in three sections. The first part included demographic questions such as gender, professional registration and years of experience. The second part consisted of closed-ended questions, measured on a 5-point Likert scale including strongly disagree (SD), disagree (D), neutral (N), agree (A), and strongly agree (SA). Questions were drawn from the literature (including books, scholarly and professional journals) and measured variables such as causes, approaches, barriers and incentives to waste minimisation. The third part comprised two open-ended questions to elicit the opinion of respondents on waste minimisation technique or strategy they have adopted previously and appropriate approaches to reduce waste. The average completion time for the questionnaire was 13 minutes.

Data collected through the closed-ended questionnaire were analysed using the Relative Importance Index (RII). The RII measures and ranks the summative frequency weighting of each variable. It is represented by the equation: $RII = \sum \frac{w}{A*N}$. Where w = weight (1, 2…5), A = highest weight, and N = number of responses. As a rule of thumb, RII values close to 1 are of high importance and vice versa (Akadiri, 2011). Reliability analysis of the questions was conducted using Statistical Package for Social Science (SPSS) v24. The Cronbach's alpha value of 0.712 was obtained, suggesting strong reliability and internal consistency of the questions. According to Hair et al. (2018), Cronbach alpha value above 0.700 is appropriate. Data collected through the open-ended section of the questionnaire were analysed using content analysis. Neuendorf (2016) noted that content analysis enables data collected to be categorised into themes and sub-theme for the purpose of comparison.

4.0 RESULTS AND DISCUSSION

A total of 60 architects were contacted via email while only 47 completed the online questionnaire, which represents about 78% response rate. This response rate is considered appropriate as compared to previous studies (Ganiyu et al., 2016; Olabode, 2018). The characteristics of the respondents are listed in Table 1, which shows that the majority of respondents are full members of the Nigerian Institute of Architects (NIA) and the Nigerian Architects Registration Council (ARCON) and have between six and ten years of experience. The high degree of participants' experience increases the reliability of the responses obtained in this study.

Table 1: Respondents' characteristics

Respondents' characteristics	Frequency	Percentage
Gender		
Male	45	95.74
Female	2	4.26
Registration status with NIA/ARCON		
Not registered	15	31.91
Graduate member	8	17.02
Associate member	6	12.77
Member	18	38.3
Fellow	0	0
Years of Experience		
3-5 years	11	23.4
6-10 years	23	48.94
11-15 years	9	19.15
16-20 years	2	4.26
Above 21 years	2	4.26

4.1 Causes of waste

The opinion of the respondents on the causes of material waste during the design process was sought. Table 2 reveals that the top three causes in the order of importance are last-minute changes due to client requirements, design changes and detailing errors, while the least cause is delay due to drawing revision and distribution. This finding is consistent with previous studies (Ekanayake and Ofori, 2000; Osmani et al., 2007; Hu, 2011; Aiyetan and

Smallwood, 2013) that identified last minute changes as one of the main causes of waste. Likewise, Odusami et al. (2012) also identified late alteration as a major cause of material waste among building construction firms in Nigeria. Clients play a major role in waste generation as a result of their indecision, which often results in changes in design, materials, specification and personnel.

Table 2: Level of agreement to design causes of waste

	SD	D	N	A	SA	Weighted total	Mean	RII
Last minute changes due to client's requirements	0	3	4	25	15	193	4.11	0.82
Design changes	0	4	2	29	12	190	4.04	0.81
Design and Detailing errors	1	1	7	26	12	188	4.00	0.80
Unclear specification	0	5	9	23	10	179	3.81	0.76
Lack of information on drawings	0	8	9	23	7	170	3.62	0.72
Clash leading to reworks	1	9	14	20	3	156	3.32	0.66
Delays due to drawing revision and distribution	0	14	13	18	2	149	3.17	0.63

SD – Strongly Disagree, D – Disagree, N – Neutral, A – Agree, SA – Strongly Agree

Factors such as change in taste, technology, budget and availability of new products or materials may be responsible last-minute design changes. Nonetheless, less waste is possible if changes were made prior to the actual construction. On the other hand, modifications made during the design process may be accommodated depending on the versatility of the designer. It is therefore important for clients to make informed decision prior to the actual construction. While clients are entitled to their choices and requests, it is the responsibility of the architect to educate them on the consequences of their decisions, which they may not be aware of. This action would not only reduce waste but could also save some money while reducing the environmental footprint. The implication of this result is that architects maintain effective communication with the client and offer professional advice on waste minimisation when performing their duties.

As shown in Table 2, design changes ranked next to last minute changes by client, which indicates that they are closely related. Design changes include a modification or a complete overhaul of the original design to fit new ideas or spaces. The design of a construction project is a working drawing subjected to minor and major changes as the construction progresses. As indicated by the respondents, a change in design is an important factor that could generate a huge amount of waste. For example, design changes that are not properly communicated between the design team or design changes requiring structural support could lead to rework, which generates waste. This finding aligns with previous studies (Osmani et al., 2008; Eze et al.,

2017) that established design changes as one of the important factors affecting waste generation. In addition, design changes were ranked as the main contributor to CW in a study conducted by Nagapan et al. (2012). Ogunmakinde (2019) described design changes as a major cause of material waste among building construction firms in Lagos, Nigeria. It can be deduced from this finding that design changes may be inevitable on construction projects. This may, however, be minimised through effective design change management, which is the responsibility of the architect. Ensuring timely and adequate communication on design with the client and other construction professionals may reduce waste generation. Furthermore, the integration of Building Information Modelling (BIM) can help to reduce waste resulting from design changes. Nevertheless, clients need to be integrated or engaged in the BIM process.

Design and detailing error ranked third by the respondents, which suggests that it is an important factor in waste generation. Design details are used to describe the relationship between building components and/or materials. They are mostly used in conjunction with specifications on construction projects to assemble components and materials. Detailing error implies an undefined, incomplete, misleading and a lack of details and specifications that could pose some challenges during construction. The details and specifications of the material or process, as provided by the design team, would provide ample information that can be understood and carried out without difficulty by construction skill workers. Several studies have reported detailing error, specification error and design error as a major cause of CW. For example, detailing error was ranked 2nd in a study conducted by Osmani and Glass (2008). Specification error in Nigeria has been reported as one of the major causes of waste (Oluwaseun and Olumide, 2013) while Al-Hajj and Hamani (2011) have shown that poor design is considered significant to material waste. The design team is responsible for and will be liable for errors in details and specifications. The implication of this finding is that the design team, in particular the architect, understands that detail design, specifications and schedules are contractual documents and are legally binding. It is therefore important for the design team to pay attention to detail by ensuring proper design documentation for effective waste minimisation (Udawatta et al., 2015). Architects need to visualise the details by figuring out how the pieces will fit into a whole before submitting the design for development approval. The design validation based on BIM, as echoed by Won et.al (2016), is an important method for reducing waste. Likewise, it will also be worthwhile for the design team to invest in continuous education and training in order to align itself with the current trend in construction materials and process technology.

4.2 Design Approaches to Waste Minimisation

Table 3 indicates respondents' ranking of the approaches to waste minimisation during the design phase. The top four approaches are design flexibility and adaptability, use of standard materials, standardisation and modular coordination of building elements, and use of prefabricated material. The least ranked approaches are specification of reclaimed or recycled materials and feasibility study of waste estimation. This finding is consistent with the results of earlier studies, which argued that design for flexibility and modern construction methods are important for waste minimisation during the design process (Yuan, 2013; Wang et al., 2014; Ajayi et al. 2017). For example, design for flexibility and adaptability was ranked 6th as a waste minimisation approach in a study conducted by Udawatta et al. (2015) in Australia. As such, respondents believed that designing buildings in response to site terrain and flexible design solutions for ease of internal space reconstruction and disassembly could contribute to successful waste minimisation by design. This implies that design documentation should include deconstruction plans to determine the level of flexibility of a design. The use of frame structure in building projects also allows for flexibility of spaces, as the internals wall can be constructed with light partitioning materials such as glass, aluminium, and medium or high-density fibreboards.

Table 3: Waste minimisation approaches during design

	NBU	RU	U	UMP	UAP	Weighted total	Mean	RII
Design for flexibility and adaptability	0	2	13	23	9	180	3.83	0.77
Material selection and use of standard materials to avoid cutting	0	3	14	22	8	176	3.74	0.75

Dimensional coordination (modular design)	2	3	15	16	11	172	3.66	0.73
Specification of structural prefabricated elements	0	7	25	10	5	154	3.28	0.66
Avoidance of late variations in designs	0	11	17	14	5	154	3.28	0.66
Guidance for hazardous waste management	3	16	11	13	4	140	2.98	0.59
Waste scenario plan	8	17	14	6	2	118	2.51	0.50
Specifying reclaimed/recycled materials	7	23	7	8	2	116	2.47	0.49
Feasibility study of waste estimation	10	18	13	4	2	111	2.36	0.47

NBU – Never been used, RU – Rarely used, USP – Used in some projects, UMP – Used in most projects, UAP – Used in all projects

Material selection and use of standard materials was ranked next to design for flexibility and adaptability. This finding implies that specification of standardised materials is crucial for minimising construction waste. The specification of standard materials can reduce the need for cutting, which generates off-cut waste. Likewise, selection of durable materials will reduce the need for frequent replacement. During construction, non-durable materials can easily break away, creating the need for replacement, which may often involve the breakup of other parts of the structure. This finding aligns with Langdon (2009), which suggest the specification of standard materials as a way of reducing waste. Alshboul and Ghazaleh (2014) have reported that standardisation of building elements reduces material waste. This was also corroborated by the findings of Ajayi et al. (2017) that stakeholders such as architects, engineers and construction managers recommend coordination of building elements as an effective waste minimisation approach. The implication of this result is for architects to understand the quality and complexities of various building materials. It would be of immense value if architects had first-hand knowledge of the typical measurements of building materials available in order to effectively coordinate dimensions of the building elements and to avoid material off cut. In addition, selection and specification of eco-friendly materials can help reduce waste generation and environmental impact (Ding, 2014; Pacheco-Torgal et al., 2014; Gibberd, 2014).

The use of dimensional coordination was ranked third among the waste minimisation techniques employed in the study area. Dimensional coordination uses a basic unit such as 1m X 1m to coordinate the spatial dimension of the design and elements of the building. This enables flexibility in design and promotes collaboration between architects and other stakeholders. Dimensional coordination reduces the possibility of creating irregular spaces, shapes and dimensions that could generate waste during construction. This finding is consistent with previous studies (Gangolells et al., 2014; Poon and Jaillon, 2002; Ajayi et al., 2017; Banihashemi et al., 2018; Esa et al., 2017) which established dimensional coordination as a measure for a more sustainable construction waste minimisation. The implication of this finding suggests that architects explore the benefits of modular coordination, in particular by collaborating with clients and manufacturers to minimise waste.

Apart from the top three waste minimisation approaches, the specification of structural prefabricated elements ranked fourth is interesting to note. The prefabrication of building elements is typically carried out in a specialised factory where multiple materials are assembled for components. When prefabricated elements are specified in a design, certain construction processes that may potentially produce waste are transferred from the site to the off-site facility. Previous studies (Wang et al., 2014; Baldwin et al., 2009; Li et al., 2015) have reported the effectiveness of prefabricated elements in material waste reduction. For example, Tam et al. (2007) revealed that the waste generated during the construction of a project can be reduced by 52% by means of a prefabrication system. The implication of this finding is that when designing projects, architects should consider modern construction methods.

4.3 Barriers

As shown in table 4, the barriers to waste minimisation at the design phase are ranked as lack of training in construction waste minimisation, poorly defined individual (design team members) responsibilities, waste accepted as inevitable, and lack of interest from client in descending order. While architects are expected to undergo formal education in order to practice, they may lack detailed training on waste minimisation. This could be responsible for design errors such as incomplete detail and specifications. Training on waste minimisation design may be acquired through formal or informal education and on the job experience. However, it is important that such trainings are practical oriented.

Table 4: Level of agreement with waste minimisation barriers

	SD	D	N	A	SA	Weighted Total	Mean	RII
Lack of training	2	6	7	23	9	172	3.66	0.73
Poorly defined individual responsibilities	1	7	7	27	5	169	3.60	0.72
Waste accepted as inevitable	2	9	8	20	8	164	3.49	0.69
Lack of interest from clients	3	13	14	12	5	144	3.06	0.61

This finding aligns with previous studies (Li. et al., 2015; Udawatta et al., 2015) that recognised design capability as a significant factor to waste minimisation through design. In addition, Ling and Nguyen, (2013) identified lack of training as a major barrier to the implementation of waste minimisation. Bakshan et al. (2017) argued, on the contrary, that the conduct of designers in CWM is positively affected by their behaviours rather than by corporate factors such as training. This implies that investment in training the design team on waste minimisation strategies is not enough to be effective in reducing waste, but the attitude towards waste minimisation is influenced by previous experience in CWM. The implication of this finding is for the construction industry to develop courses or modules on waste minimisation design, which may be offered to architects as part of their continuous professional development. This would ensure that architects have the professional knowledge to minimise waste through design, even though such knowledge is not acquired from their formal education. Likewise, architects need to demonstrate positive attitudes and behaviour towards waste minimisation, which is achievable when they take more responsibility for their actions.

4.4 Driving factors

Table 5 presents findings on factors that can drive waste minimisation during the design process. Based on the perception of respondents, training and waste management policy were ranked first and second respectively. This finding suggests that the training of architects is essential in order to minimise waste resulting from design. Beyond formal education, there is need for hands-on practical training. Such training would not only improve their design skills but could also reduce the volume of waste that goes to landfill.

Table 5: Level of agreement with waste minimisation driving factors

	SD	D	N	A	SA	Weighted Total	Mean	RII
Training	0	1	3	21	22	205	4.36	0.87
Waste management policy	1	1	4	18	23	202	4.30	0.86
Legislation	2	2	10	17	16	184	3.91	0.78
Financial rewards	1	5	10	24	7	172	3.66	0.73

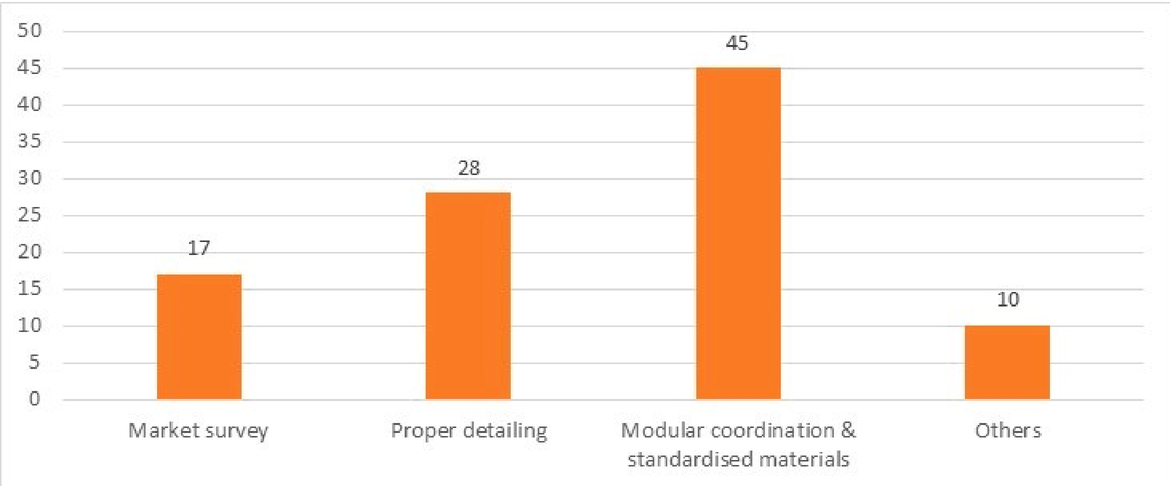
This finding further confirms lack of training as a barrier to effective waste minimisation by design. However, it is consistent with previous studies (Wong and Yip, 2004; Kulatunga et al., 2006; Lu and Yuan, 2010; Gangolells et al., 2014; Wang et al., 2014; Adewuyi and Odesola, 2016; Ogunmakinde, 2019; Ajayi et al., 2017; Li et al., 2015) that affirmed the importance of waste minimisation training. The implication of this finding is for architects to consider waste minimisation design strategies as part of their professional development and to take the necessary steps to update their knowledge base, in particular with technology and innovations.

While environmental management policies and regulations exist in Nigeria, none of them directly address construction waste (Ogunmakinde, 2019). This suggests that there are no policies for the re-use and recycling of construction materials waste, which may be the reason why respondents identified the implementation of waste management policy and legislation (ranked 2nd and 3rd respectively) as potential factors that could minimise waste during the design phase. For instance, waste minimisation policies, such as site waste management planning, may compel architects to reduce waste through design and specification. In addition, the waste minimisation policy could also ensure that the recycling and re-use plan of materials are included in the design. Previous studies (Lu and Tam, 2013; Glazyrina, et al., 2006; Tam and Tam, 2006; Hao et al., 2008) have proven that waste minimisation policy is an effective strategy for reducing material waste. This finding suggests that CWM policies can improve the design process. It also has implication for the industry and the government to jointly create a design checklist, which would provide architects with a list of waste minimisation actions to be checked before the project is approved. The implementation of a design checklist may be effective in persuading architects to produce zero-waste designs and making them more responsible for their actions to minimise waste. Likewise, financial rewards (least ranked) including wage increase, bonuses, commissions and profit sharing can be effective in encouraging waste efficient designs.

4.5 Waste Minimisation Strategies

Respondents were asked to respond to an open-ended question on the techniques or strategies they have adopted, and which have proved to be effective in minimising waste during the design process. The finding shown in Figure 1 reveals that less than two-quarters (45%) of respondents used modular dimension in their designs and have used standardised materials. This would not only reduce design time, especially when Computer Aided Design software is used, but also reduce material waste and facilitate construction processes. This finding aligns with previous studies (Ajayi, 2017; Ogunmakinde, 2019) that identified modular coordination as one of the effective design strategies for minimising material waste. Subsequently, more than one-quarter (28%) of the respondents claimed that they used proper detailing as a measure to minimise waste. Proper detailing involves the provision of adequate information on the various elements of the proposed building. Such information may ensure appropriate cost estimation and minimise over ordering of materials that could minimise waste.

Figure 1: Waste minimisation strategies



Market survey is another strategy adopted by the respondents. Less than two-tenths (17%) of respondents indicated that the market survey was effective in reducing waste product or material waste. Market survey provides an opportunity for architects to understand the available materials, including their size and functionality. This will allow careful planning of the space for materials and elements when designing the structure. Other strategies identified include communication with other professionals, use of standard and specifications, educating clients on waste minimisation, designing with less variety of materials, minimising design changes and design for deconstruction and material reuse. The implication of this finding is for architects to think through the design and consider waste minimisation options.

5.0 CONCLUSION

Unlike previous studies examining the causes, effects, attitudes and perceptions of construction professionals to material waste, this study is unique in that it specifically examined the strategies employed by architects during the design phase to minimise construction material waste. It also identified the causes of waste, approaches and barriers to effective waste minimisation. The three main causes of the design waste found in the study are client's last-minute changes, design changes and detailing errors, suggesting that both the client and the architect are responsible for the generation of waste at the design phase. In addition to the roles and responsibilities of the architects surveyed, their top three approaches to minimising material waste are the use of design for flexibility and adaptability; the selection and use of standard materials; and the use of dimensional coordination in design. The study found that such approaches would be effective if the architects took some time to consider the environmental impacts of the design and not just the aesthetic and comfort of the proposed occupants. Barriers to waste minimisation were identified as lack of training, poorly defined individual roles, waste accepted as inevitable and lack of client interest. While such barriers may require some drastic measures, training, waste management policy and legislation were identified as potential factors that could drive waste minimisation during the design process. The implication of the findings is that architects should take responsibility for minimising waste during the design phase by taking additional training and educating their clients. The limitation of this study is that the findings may not be generalizable to the Nigerian Institute of Architects. Although only practicing architects in Akure were surveyed in this study, the same waste minimisation strategies are likely to be used across the country. The study thus fills the void in the architects' strategies for waste minimisation at the design phase. Future studies can include architects from other States of the country. The perception and responsibilities of clients to waste minimisation during the design process, as well as the impacts of architects' behaviours, may also be explored.

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